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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report 09-84-03	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COGNITIVE ASYMMETRY AND OCCUPATION: COMPUTER PROGRAMMERS, STUDENTS, AND BANK PERSONNEL		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Part I. Harold W. Gordon Part II. Harold W. Gordon Kathy Kronz		8. CONTRACT OR GRANT NUMBER(s) N00014-83-K-0208
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Pittsburgh Western Psychiatric Institute and Clinic Pittsburgh PA 15213		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 196-186
11. CONTROLLING OFFICE NAME AND ADDRESS Engineering Psychology Group Office of Naval Research Arlington, VA 22217		12. REPORT DATE 6 September 1984
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Dr. Eugene Glove, Science Officer Office of Naval Research 1030 Green Street Pasadena, CA 91106		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES The cooperation of the Human Resources Department of Equibank, Pittsburgh, the University Computing Center, and Dr. Daniel Doud of the Computer Science Department of the University of Pittsburgh is gratefully acknowledged. Research was supported by the Engineering Psychology Programs, Office of Naval Research.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Cognitive Asymmetry Computer programmers Cognitive Performance Laterality Cognitive Processes Occupation Cognitive Style Personnel selection Hemispheric specialization		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) System analysts and computer programmers of a university computer center performed better on visuospatial tasks associated with the right hemisphere. The cognitive profile was significantly different although the overall performance was not different between the groups. In a second study with an intermediate computer class, there was a significant correlation between the cognitive profile favoring visuospatial skills and scores on computer projects in which the students used their own ingenuity. There was no correlation with scores that depended on class notes		

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S/N 0102-LF-014-6601

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COGNITIVE ASYMMETRY AND OCCUPATION: COMPUTER PROGRAMMERS, STUDENTS, AND BANK PERSONNEL

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September, 1984

Technical Report 09-84-03

This research was sponsored by the Human Factor Engineering, Psychological Sciences Division, Office of Naval Research, under contract No. N00014-83-K-0208, Work Unit Number, NR 196-186.

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ABSTRACT

System analysts and computer programmers of a university computer center performed better on visuospatial tasks usually attributed to the right cerebral hemisphere. By contrast, subjects from a human resources department of a bank performed better on verbal/sequential tasks associated with the left hemisphere. The cognitive profile was significantly different although the overall performance was not different between the groups. In a second study with an intermediate computer class, there was a significant correlation between the cognitive profile favoring visuospatial skills and scores on computer projects in which the students used their own ingenuity. There was no correlation with scores that depended on class notes nor with scores on examinations. These results suggest that knowing the cognitive profile may be important in determining success in certain occupations.

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Cognitive Asymmetry and Occupation:

Computer Programmers, Students, and Bank Personnel

It is tempting to dichotomize people into "right brain" thinkers or "left brain" thinkers and attribute such thinking to type of occupation. There is a certain amount of face validity in this exercise: people in the artistic professions such as architecture, sculpture or design are likely to excel in the visuospatial skills normally attributed to the right hemisphere. Similarly, lawyers or accountants are likely to excel in verbal skills and possibly sequential memory as well. While the relationship between cognitive preference and those more obvious occupational categories has been shown, these same individuals do not differ in their left/right asymmetries for brain activation (Dumas and Morgan, 1975; Arndt and Berger, 1978). Simply because an artist is better at visuospatial tasks associated with the right hemisphere, that hemisphere will not necessarily show greater activation than, say, that of a lawyer performing a visuospatial task. Apparently, then, individuals may be more efficient at one type of skill or another without that fact being reflected in electrical recordings of the brain.

While aptitude, achievement, and IQ tests have been used for years to predict success in education, in occupational goals, and in society, very few have taken into consideration the actual functions of the brain in the test construction. This is rather startling since the brain is the basis of all behavior. It would seem that a valid measure of specialized brain function would be more valuable as a predictor than a test not validated for brain function. Research has indicated that such a test can be applied with positive results. For example, visuospatial tests of the Cognitive Laterality Battery (Gordon, 1983) were successful in distinguishing combat pilots from

helicopter pilots (Gordon et al., 1982). Since the tests used on that Battery reflected specialized brain function, other research bearing on those specialized brain functions would also relate to selection of combat pilots.

The Cognitive Laterality Battery (CLB) is constructed of "visuospatial" subtests and "verbal/sequential" subtests that demonstrate superior functioning attributed to the right and left hemisphere, respectively. These tasks were taken or adapted from studies of patients with unilateral lesions or with complete midline division of the brain (commissurotomy), and from studies of normal subjects. The Battery has been standardized on male and female children and adults. Factor analyses demonstrate 2 main factors which correspond to tests chosen to reflect the specialized functions of the right and left hemispheres. An individual who performs relatively better on the visuospatial subtests is said to have a right "hemisphericity". That is, this person has a preference for, or a better performance on, tests associated with the right hemisphere. Similarly, a person with a left hemisphericity performs better on the verbal/sequential tests. This does not necessarily mean that the left hemisphere is more active in the case of left hemisphericity. The strongest assertion that can be made is that left hemisphere processes are more efficient than right. At the very least, it can be said that left hemisphericity means the individual performs better on tests normally attributed to the left hemisphere, leaving open the question of location. For a given individual in either case, the actual location(s) of these processes in the brain may vary in comparison with the next individual.

The next step for validation is to determine whether better performance on tests associated with one hemisphere or the other predicts performance in specialized occupations. In a preliminary study (Gordon, 1978; 1983) with 9 and 10 year old children in a school program for "gifted" children, better performance was obtained on tests associated with the left hemisphere for

those children who had chosen a creative writing class. Better performance on "right" tests was obtained by children who had chosen a model building class. In a companion study, 12-14 year old children who had chosen a computer programming class (in the Summer, 1978 before computers were popular) performed much better on the visuospatial tasks of the Cognitive Laterality Battery.

The present study extends the finding with the gifted children in the computer class to college students taking a computer class, and to professional programmers and system analysts in the university computer center. A comparison group are individuals from the human resources department of a local bank who were tested to compare job complexity to cognitive function (Gordon, Charns, and Garamoni, 1984). The study offers a first step in relating cognitive functions to occupational types.

Part I

Methods

Subjects

University Computer Center. Twenty-one employees (18 male; 3 female) from the university computer center were tested with the Cognitive Laterality Battery (CLB). The job titles of the subjects included "systems analysts/programmers", "programmers/systems analysts" and supervisors of these groups. The main distinction other than years of experience seemed to be the percentage of time designing systems for the center or in troubleshooting and programming. The supervisors had the most experience followed by the systems analyst/programmer and then the programmer/system analyst. An estimate was made of the amount of time the subjects spent as "analysts" or "programmers".

The subjects ranged in age from 23 to 48 (mean=33.28; median=33). All were college graduates primarily with degrees in computer science. Subjects were recruited by higher administrators but informed consents were obtained

from each prior to testing and evaluation. Not all subjects in the departments volunteered; only 1 who arrived at the test session declined during consent procedures.

Bank Human Resources. Twenty-three employees (5 male; 18 female) including clerical staff, secretaries, and managers from the human resources department of a bank were tested. The ages ranged from 25 to 49 (mean=34.43; median=36). The subjects were recruited by the department head but consent forms were read and signed prior to testing.

Test Instruments

The Cognitive Laterality Battery. The Battery consists of eight tests and, along with instructions, is presented on 35mm slides together with audio cassettes. The subjects observe or listen to the stimulus presentation and respond on special answer forms passed out for each test. The tests had been chosen to reflect the visuospatial and verbal/sequential functioning of the right and left hemispheres respectively. Factor analyses on the normative population confirmed the qualitative, orthogonal differences between the function types.

The tests were administered in a fixed order alternating according to factor type. The following is a description of the tests in the order presented:

- (1) Serial Sounds: A total of 12 sequences of 4, 5, 6 and 7 familiar sounds (e.g., baby, bugle, rooster, bird, telephone, etc.) were played from a pre-recorded tape. The subject's task was to write the items in the same sequential order. The onsets of each sound in the sequence were spaced at 2-second intervals. The subject waited for a start signal at the end of the sequence before the answer. Scoring was based on the number of items correctly reported in sequence whether or not the whole sequence was correct.

- (2) Localization: A photographic slide containing a black "x" within a black frame on a white background was flashed on a screen for 3 seconds. The subject had a similar frame on the answer sheet and marked with a pencil the location of the "x" within it. There were 24 slides arranged in pseudorandom order counterbalanced such that the same number of "x's" appeared in each of the four quadrants. Subject's score was the total error in millimeters accumulated over all trials. (This was the only test in which a high score represented a poor performance).
- (3) Serial Numbers: A total of 9 sequences of 4, 5,...9 single digit numbers were presented at a rate of 1 per second. At the end of each sequence the subject was required to write the sequence in the same order as presented. The scoring was the same as Serial Sounds in which partial credit was given to correct fragments of sequences even if the whole sequence was not correct.
- (4) Orientation: (Adapted from Shepard and Metzler, 1971). The stimulus was a slide of 3, three-dimensional, S-shaped constructions of 10 stacked cubes. Two constructions were identical but rotated in space around a vertical axis. The third was the same as the other two but appeared as the mirror image. The subject was given 15 seconds to select the two constructions that were alike. There were 24 trials.
- (5) Word Production, Letters: The subject was given one minute to write as many words as possible, beginning with a given letter of the alphabet. The subject's score was the total of three attempts, each time with a different letter.

- (6) Word Production, Categories: The subject listed as many animal and food names as possible. One minute was allowed for each category. The subject's score was the total of the two categories.
- (7) Form Completion (Closure Speed): (Adapted from Thurstone and Jeffreys, 1966; French, Ekstrom, and Price, 1963). The stimulus was a slide containing 6 incomplete silhouette drawings of common objects or scenes appearing white on a blue background. The items were selected from two similar tests and chosen to be as culture-free as possible. The task was to identify and describe, in a word or two, each of the 6 drawings. Forty-five seconds were allowed for each slide and answers were written on special answer sheets. Six slides were presented for a total of 36 items.
- (8) Touching Blocks: (MacQuarrie, 1953). The stimulus was a slide of one large cube construction made up of 8-10 stacked rectangular blocks. The blocks were stacked such that anywhere from 2 to 8 blocks were adjacent to (touching) any one block. For each stimulus slide, 5 of the blocks were numbered and the subject was given 45 seconds to indicate the number of touching blocks for each of the numbered blocks. There were 6 slides for a total of 30 items.

Analysis of performance on the Cognitive Laterality Battery. Standard scores were derived from means and standard deviations of 250 adults drawn in part from a non-college population and in part from an undergraduate and graduate student population. The scores are calculated separately for males and females. Mean scores for the two main factors were calculated by averaging the standard scores for the visuospatial tests (called A after "Appositional" (Bogen et al., 1972) and verbal/sequential tests (called P after "Propositional"). A cognitive profile called the Cognitive Laterality Quotient (CLQ) is defined by the difference between the two averaged scores: $CLQ = A - P$. For a

"normal" subject, $CLQ = A - P = 0$, by definition since all are linear combinations of standard scores. When $CLQ > 0$, the visuospatial tests are performed better; when $CLQ < 0$, the verbal/sequential tests are performed better.

The CLQ is the dependent variable that defines the relative processing efficiency of brain functions as determined by the CLB subtests. A measure of overall ability can also be obtained by averaging the two averaged cognitive measures: Cognitive Performance Quotient, $CPQ = (A + P)/2$.

Procedure

Subjects were tested in groups of up to 20 in comfortable seminar rooms at their place of work. The session started with a brief description of the project and consent procedures. Testing proceeded, administered by 2-3 proctors. The entire session lasted 1-1/2 hours.

Results

Employees of the university computer center had cognitive profiles favoring tests associated with the right hemisphere by nearly 1/2 standard deviation: $CLQ = +0.415$ (s.d.=0.822). This average differed significantly from zero: $t = 2.10$, $p < 0.05$, $df = 20$. Three-fourths (16/21) of the subjects had this profile, significantly more than the number of subjects with profiles favoring the left hemisphere ($p < 0.05$). The distribution of scores tended to be normal ($\chi^2 = 10.97$, $p = 0.10$, $df = 6$) with the mean shifted to the right (See Figure 1).

--Place Figure 1 about here--

Employees of the bank had the opposite cognitive profile in favor of tests associated with the left hemisphere. The average score was about 1/3 standard deviation in the "left" direction $CLQ = -.310$ (s.d.=0.781). This suggested a trend ($t = 1.86$, $p < 0.10$, $df = 22$) away from zero. Nevertheless, 17 of the 23 subjects had this profile; again this number is significantly more than the number with the opposite profile ($p < 0.05$, binomial). The distribution of

the scores was normal ($\chi^2=3.9$; $p>0.10$, $df=5$) but shifted to the left (See Figure 2).

--Place Figure 2 about here--

The difference between the two groups is clear. The difference in average CLQ between the groups is nearly 3/4 of a standard deviation, which is significant ($t=2.83$, $p<0.01$, $df=42$). The groups did not differ significantly ($t=1.13$, $p>0.10$) in overall performance on the CLB in spite of the likelihood of more schooling for the computer group. The difference between the groups was the cognitive profile as was already evident from the significant difference in the CLQ. The employees from the bank were slightly below the norm for tests associated with the right hemisphere ($A=-.123$) but above the norm for the tests associated with the left hemisphere ($P=+0.187$). The employees from the university computer center had the reverse profile. They were exactly at the norm for tests associated with the left hemisphere ($P=-0.010$) but above the norm for tests associated with the right hemisphere ($A=+0.405$).

One final trend is worth noting. The computer personnel were classified by their supervisors according to the percentage of time they spent as a "system analyst" and the percentage of time they spent as a "programmer". There was a trend for a positive correlation between the ratio of time as a system analyst compared to a programmer ($\%SA/\%P$) and the Cognitive Laterality Quotient (CLQ): $r=0.41$, $p<0.10$. This means that the more time an individual spent as a system analyst, the more asymmetrical the cognitive profile in favor of skills attributed to the right hemisphere.

Discussion

It is clear from these results that most employees of the university computer system are more competent on tests of point localization, 3-dimensional imaging, and form completion than verbal and sequential skills. This finding raises several questions. Has this profile always existed with these

individuals or has it been developed with training? Were these individuals attracted to the field of computer programming and systems analysis because of their cognitive profile? Were they more likely to succeed in computer classes throughout schooling because of their cognitive profile?

The next study was designed to provide information on this last question and determine whether hemisphericity was relevant to programming in assigned computer course projects. A course was selected in which the students had projects for which they were to design and write computer programs. Scores on various aspects of these projects, as well as scores on a final examination served as the dependent variables with which to compare the cognitive profiles.

Part II

Methods

Subjects

Twelve subjects (4 males; 8 females) from a class of about 50 volunteered for the study. (An additional 4 foreign students had volunteered but their data were not used because appropriate norms were not available for the cognitive tests). The subjects were recruited by request from the lecturer in the class and by the principal investigator. No compensation was made to the subjects except feedback on their individual cognitive performance. Furthermore, the students had to be willing to remain after class for testing which was done in a 1-1/2 hour session following a late afternoon, regular class period.

The CLB was administered following consent procedures as described for Part I. Scores for class projects and examinations were compiled as usual by the class lecturer and teaching assistants. Separate scores were given to

sections of the project that reflected 1) material learned in class, 2) creative programming or problem solving on the part of the student and 3) style of writing the computer program. Neither the lecturer nor the assistants knew the results of the cognitive testing. The subjects and lecturer knew that a comparison between the cognitive profile and project scores would be made but expected results were not discussed.

Instruments

Cognitive Laterality Battery. See Part I.

Projects. Four computer projects were included in which students were required to write a program to:

- I. 1. Organize a grade file by reading an existing list of grades and printing it.
2. Eliminate duplicate records and print the new file.
3. Sort the file by going through one file, picking out values and inserting them in the proper order in a new file.

Part 1 had been demonstrated in the class lectures. Parts 2 and 3 required student ingenuity.

- II. 1. Read in values from a data file.
2. Solve a mathematical puzzle which must systematically delete a set of predetermined values.
3. Print the output.

Parts 1 and 3 required direct application of test material and class lectures. Part 2 involved some ingenuity.

- III. 1. Convert a number in a given pair to the base of the second number of the pair.
2. Print out 3 columns of numbers where the first 2 columns were the initial number pair, and the third was the converted number.

Only direct application of classroom and text material was needed to solve this problem.

- IV. 1. Read information about a maze.
2. Find a pathway out of the maze.
3. Print the path taken if the maze can be solved.
4. If there is not solution, then print an appropriate message.

Parts 1, 3, and 4 demonstrate direct application of class and test materials. Part 2 required ingenuity on the part of the student.

Examinations. There were 2 examinations for the semester. On each examination, one section required the student to supply missing words (fill in the blanks). A second part required the student to write a small section of programming code to solve brief problems.

Results

The Cognitive Laterality Quotient (CLQ) is positively correlated with the total of the "creative" subscores for the 4 programming projects ($r=0.680$, $p<0.02$). The creative parts of the projects are those in which the student had to use some ingenuity to complete the assignment. By contrast, the correlations between the CLQ and subscores for project components that required only direct application of class materials was low and non-significant, as were the correlations between CLQ and subscores for programming style. The total score, which includes all subscores for the 4 projects was correlated with CLQ ($r=-0.575$, $p<0.05$), but the CLQ was not correlated with the total score for the two examinations (see Table 1).

--Place Table 1 about here--

There was a pattern of positive correlations between the CLQ and the creative subscores for each test ranging from $r=0.287$ to $r=0.542$; only the highest was marginally significant. (See Table 2) The same correlation pattern was seen between CLQ and the total scores for each project. The range

of r 's was from 0.407 to 0.580; the last can be interpreted as significant at the 5% level. The correlations between the subscores for applying classwork and for programming style were inconsistent and generally non-significant.

--Place Table 2 about here--

The pattern of correlations between the visuospatial skills, A, and the verbal/sequential skills, P, is also of interest. "A" was consistently positive in its correlations, indicating that better visuospatial skills corresponded with better scores on the programming projects. Conversely, correlations with "P" were consistently negative, suggesting that higher verbal/sequential skills were associated with poorer performance on the programming assignments. There was no consistent relationship between overall cognitive performance (CPQ; the sum of A and P) and scores on either the projects or the examinations.

Discussion

These data demonstrate a relationship between a specialized cognitive profile and programming ability as reflected by project scores in an intermediate computer class. It is notable that the strongest correlation occurred between the cognitive profile -- the Cognitive Laterality Quotient (CLQ) -- and the project components that required student ingenuity. There was no such correlation between the CLQ and the programming parts that could be garnered from class notes, nor from scores given for programming style. Although there was also a correlation between CLQ and the total project score, it was clear that the correlation with cognitive profile was specific to the creative parts of the project. A lack of correlation with the examinations strengthens the idea that the cognitive profile specifically predicts creative, integrative ability, rather than overall performance.

An association between cognitive profile and programming skill is reflected both in negative correlations with P, the verbal/sequential skills,

and positive correlations with A, the visuospatial skills. Furthermore, there is no correlation with overall cognitive performance (The Cognitive Performance Quotient, CPQ). These data suggest that a preference for visuospatial over verbal/sequential skills is an asset for writing computer programs or parts of programs, especially those parts which cannot be completed using prior-learned "dictionaries" of applicable programming code.

Although the number of subjects is small, the data are consistent with the findings for the university computing center programmers and system analysts. In that group, the CLQ was positive (favoring visuospatial functions) for 3/4 of the employees with an average value of nearly 0.5 standard deviation from the "normal" 0. Thus there is confirmatory data from the novice and professional relating specialized cognitive functions and programming skill, but the longitudinal study is clearly lacking. Whether "right hemisphere" students of computer programming are at an advantage at all levels of training remains to be seen. Also, there may be a number of areas in the programming profession such as "debugging", improving efficiency, or condensing program code for which a "left hemisphere" profile is favored. These data are yet to be collected but suggest the cognitive profile is an important dimension to be considered.

General Discussion

These studies have demonstrated first that individuals holding bank jobs (excluding tellers) tend to perform better on tasks requiring verbal fluency or sequential memory than they do on visuospatial tasks. Secondly, and in contrast to bank personnel, systems analysts and programmers have a significant cognitive profile favoring functions of the right hemisphere. The results for these 2 different groups support the contention that skills associated with specialized brain functions may be meaningfully related to certain occupations, even when not obvious from the job title.

The important finding is not that performance on a certain verbal or sequential task is associated with occupations of these job holders, but that these particular tasks are valid measures of specialized brain function. For example, bank personnel with a left hemisphere cognitive profile might also do well in a vocabulary test. Even though this is a language task, there is evidence the right hemisphere has a sizable lexicon and significant semantic comprehension (Zaidel, 1976). Therefore, an above-average performance by bank personnel on a vocabulary test would have no implication for organization of specific brain function. Verbal fluency and sequential memory are not likely to be performed by the right hemisphere. Therefore, it is consistent with the findings that the bank personnel in this study have functional organization favoring functions of the left hemisphere.

The cognitive asymmetry favoring functions of the right hemisphere for the systems analysts was not necessarily expected. One could have argued that the task of computer programming would require logical, step-by-step thinking, thus favoring functions attributed to the left hemisphere. For the subjects in this study, this was clearly not the case. In addition, it appeared that employees whose jobs involved more duties typical of a "system analyst" compared to a programmer were those with even greater scores on visuospatial skills.

The question was raised as to whether individuals with right hemisphere profiles are attracted to computer work or whether both left and right profile individuals are attracted to computers but those with the right profiles are more likely to succeed. Results from the second study support the latter alternative. Students in the intermediate computing class tended to favor visuospatial functions as a group but more importantly, there was a significant correlation between the right hemisphere cognitive profile and scores on the creative parts of the programming projects. In general, there was no

correlation for simply implementing class-learned material or for standard examinations. Presumably, more advance computer courses depend more heavily on creative programming thereby favoring to an even greater extent those individuals with a right hemisphere profile. The suggestion from these preliminary results at the beginning level as well as the results from the professional programmers is that cognitive profile may be a valid indicator of success in some parts of the computer field. Confirmation of these hypotheses will require cross-sectional and longitudinal testing throughout training in computer technology.

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Table 1. Pearson Correlations between Cognitive Measures
and Totals on Sub-parts of Computer Projects.

(n=12)

	A "right"	P "left"	CLQ =A-P	CPQ =(A+P)/2
Class material	0.478	-0.110	0.426	0.349
Ingenuity	0.491	-0.556*	0.680***	0.083
Style	0.388	-0.092	0.348	0.281
Total Score	0.529*	-0.310	0.575**	0.269
Total Examinations	0.162	-0.097	0.177	0.081

*<.10

**<.05

***<.02

Table 2. Pearson Correlations between
Cognitive Measures and Sub-parts
of Individual Projects

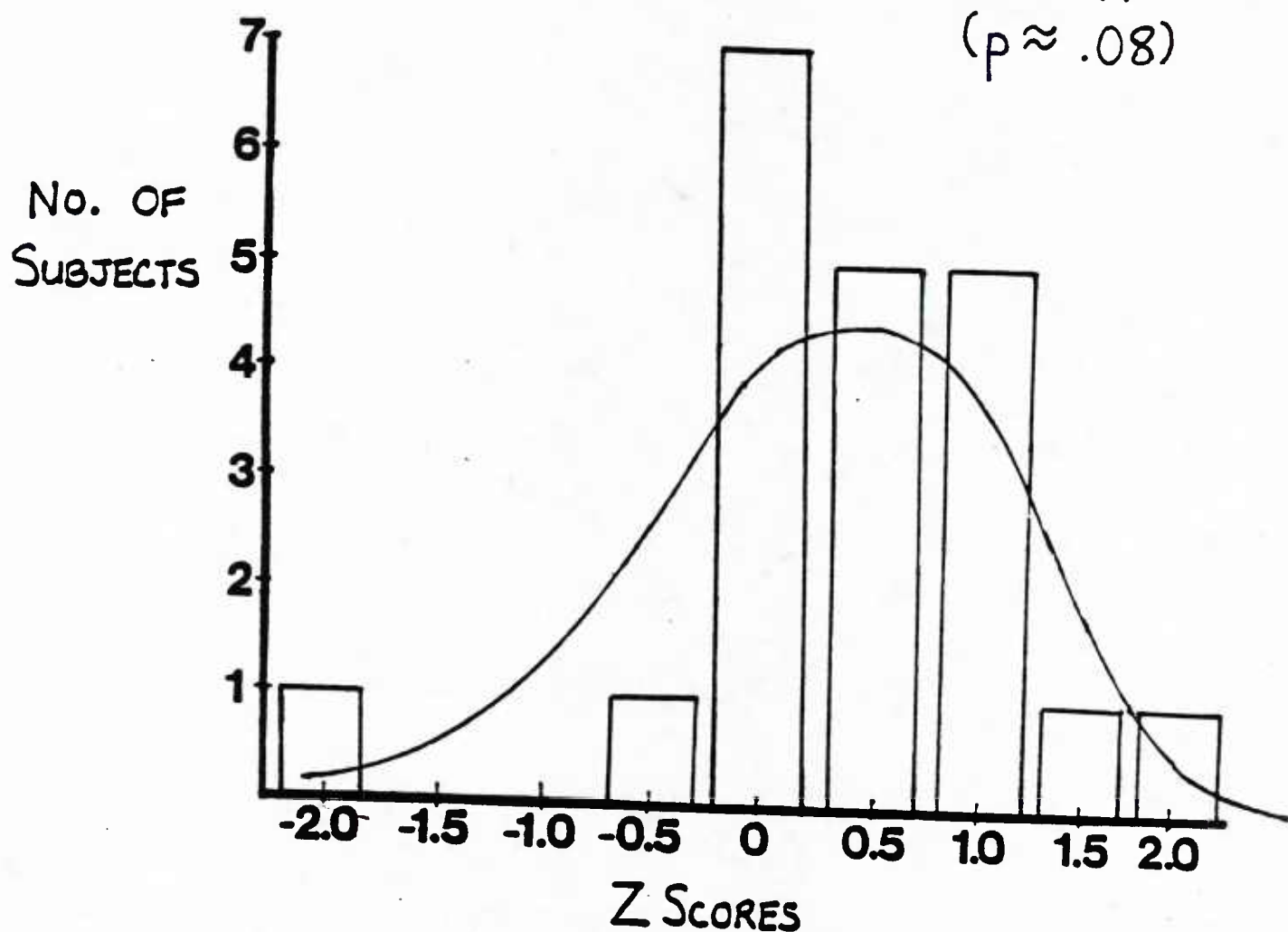
(n=12)

	A "right"	P "left"	CLQ =A-P	CPQ =(A+P)/2
<u>Project 1</u>				
Class Material	0.382	0.281	0.139	0.508*
Ingenuity 1	0.440	0.093	0.287	0.442
Ingenuity 2	0.441	-0.373	0.542*	0.153
Style	0.381	0.280	0.140	0.507*
Total	0.544*	0.008	0.413	0.480
<u>Project 2</u>				
Class Material	-0.018	-0.049	0.013	-0.046
Ingenuity	0.135	-0.449	0.348	-0.161
Style	0.430	-0.147	0.410	0.284
Total	0.343	-0.264	0.407	0.135
<u>Project 3</u>				
Class Material	0.433	-0.399	0.550*	0.130
Ingenuity (None)	-	-	-	-
Style	0.125	-0.338	0.281	-0.101
Total	0.407	-0.491	0.580**	0.050
<u>Project 4</u>				
Class Material	0.275	-0.690***	0.588**	-0.189
Ingenuity	0.328	-0.378	0.458	0.052
Style	-0.193	-0.404	0.072	-0.419
Total	0.252	-0.491	0.461	-0.085

* $<.10$; ** $<.05$; *** $<.02$

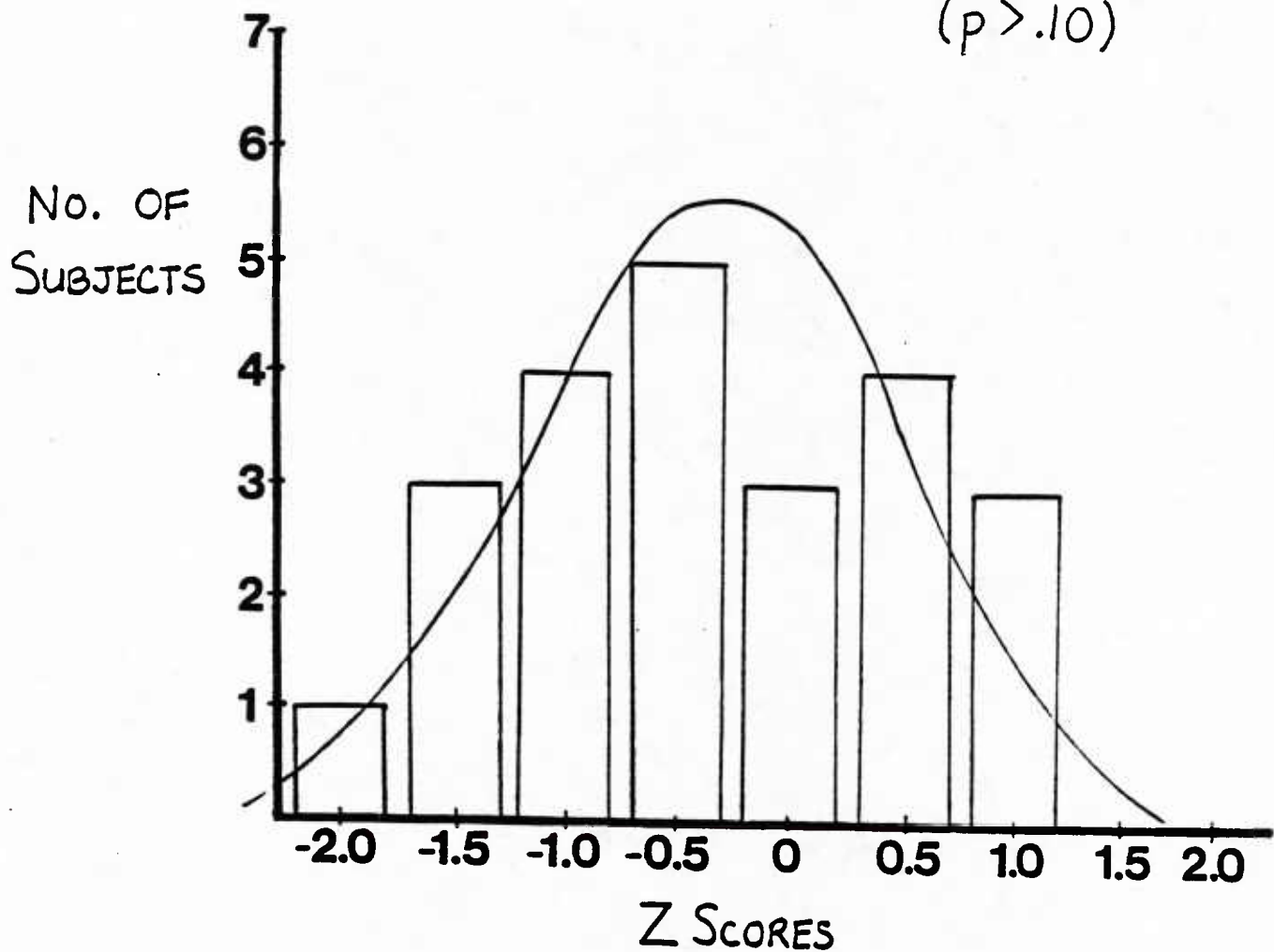
DISTRIBUTION OF COGNITIVE PROFILE SCORES
UNIVERSITY COMPUTER CENTER
(N=21)

$$\chi^2 = 10.97$$
$$(p \approx .08)$$



DISTRIBUTION OF COGNITIVE PROFILE SCORES
BANK HUMAN RESOURCES
(N=23)

$$\chi^2 = 3.93$$
$$(p > .10)$$



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